Design of a Portland Cement Plant

H. G. R. Quin

1906

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THE DESIGN OF A PORTLAND CEMENT PLANT.

Utilizing

Blast-Furnace Slag.

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THESIS

Presented to the

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of the

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By H. G. Quin

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in

CHEMICAL ENGINEERING

June 1st, 1906.

Accepted. W. T. McClement
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The Design of Portland Cement Plant
Using Slag-Limestone Mixture.

The object of this thesis is the design of a plant for the manufacture of Portland cement, which is to have a capacity of 500 barrels per day of 24 hours. The raw materials to be utilized are blast-furnace and other slags produced in iron and steel industries. The plant is to manufacture a true Portland cement using a slag-limestone mixture, where the slag takes the place of the clayey materials usually employed in Portland cement manufacture. Beside the object above stated the author had the end in view of becoming acquaninted with the chemical side of the manufacture, as well as the engineering so before entering into a discussion of the plant and machinery, a brief concideration of the former will be made.

Nature of Slag Portland Cement.

This cement is essentially a true Portland and not a real slag cement, the method of manufacture being very little different from that of common Portland cement. This cement has very good qualities and is vastily superior to any slag cement made without calcination. These slag cements which occasionally ~~is had to~~ are referred to are mixtures of slag, which has been suddenly cooled by quenching in water, and slaked lime. This addition of lime increases the hydraulic properties, which however, are possessed in a large degree by the suddenly cooled slag in itself. In the manufacture of Iron Portland cement as it sometimes called, slag is utilized as the clay ingredient is in the usual clay-limestone mixture.

1848

Nature of Slag which can be Utilized.

All slags cannot be utilized in Portland cement manufacture, and hence a slag brick plant which can use slag of inferior qualities is usually run in conjunction with cement plant so that there will be no financial loss, for furnace men pay no attention to the slag qualities when those of the iron are inconsideration. Slag consists essentially of (Al_2O_3) alumina, (CaO) lime, (SiO_2) silica, small percentages of (FeO) iron oxide, (MgO) magnesium oxide, and sulpur. Slag may therefore be considered a very impure limestone or very calcareous clay from which carbon dioxide has been driven off. The slag to be of any use must be cooled suddenly, which is best done by running it into water, while in a molden condition. The more basic a slag is in its chemical properties, the more valuable it is for cement manufacture. Those especially suited for this purpose should show from 27 to 32 per cent silica 10 to 22 per cent alumina, 48 to 56 per cent lime, 1 to 2 per cent magnesium and not above 1.25 per cent of sulphur. The following table shows the limits in chemical composition of slag used in a German cement plant.

SiO_2	30-35
Al_2O_3	10-14
FeO	.2-1.2
CaO	46.49
MgO	.5-3.5
SO_3	.2-.6

Slag has one quality, which beside cheapness, makes it use advantageous and that is the fact that the lime it contains is already decarbonized and hence requires less fuel for

clinkering than a clay-limestone mixture.

Nature of the Limestone.

The other raw material used in making slag Portland cement is limestone, which should have the following qualities;

1. Uniformity of composition and structure.
2. Should be fine grained.
3. Low per cent of magnesia so that the per cent of magnesia in cement will not exceed three per cent.
4. The alumina content should not be high enough to disturb proper alumina-silica ratio.
5. Content of Fe_2O_3 must not be too high so as to increase the amount of this substance in the cement beyond 4%.
6. Should be free from concretionary iron sulphide and low in sulphur.

Method of Making Portland Cement from Slag-limestone Mixtures.

There are three methods in use for the manufacture of Portland cement from slag-limestone mixtures. These are briefly as follows:-

(1) The granulated slag is dried and powdered very finely. Before, the final grinding a calculated amount of limestone which has been dried and crushed similarly to the slag, is added. This mixture is clinkered by running it into rotary kilns, after whichprocess the resulting clinker is ground. Portland cement of high grade is the result.

(2) The granulated slag is dried and mixed with proper amount of limestone which has been previously dried and powdered.

Slaked limed is added to bring the cement up to correct composition. After fine pulverization in tube mills the mixture is made into a slarry by the addition of 8% of water and is then formed into bricks. The bricks are then built into chamber kilns and burnt. Then the clinker is treated as before.

(3) The slag is granulated by allowing the molten material to run into water and is mixed, while still wet, with crushed limestone in proper proportions. The mixture is then run through a calciner whose temperature is enough to partly powder the material and to reduce most of the limestone to CaO. The mixture is next clinkered in rotary kilns.

Of these three processes, the second is unadapted to American engineering practice, while the third is not used in this country although apparently a good process.

References on Slag-limestone Mixtures.

Eckel, E. C., Cements, Limes, and Plasters

P.411-415

Eckel E. C. Preparation of slag limestone mixtures

Municipal Engineering

V 25 P. 227-230

Jantzen, Utilization of Blast Furnace Slag.

Journal of the Iron & Steel Institute

#1 P. 634-7, 1903.

Lathbury and Spackman,

Clinton Cement Co. Plant,

Pittsburg, Pa.

The Rotary Kiln P. 82-85

Von Schwarz, C., Portland Cement from Blast Furnace Slag,
Journal Iron & Steel Institute,
1903 #1 203/230.

Von Schwarz, C., Utilization of Blast Furnace Slag,
Journal of Iron & Steel,
1900 #1 P. 141-152.

The process for which the plant described in this thesis was designed has been referred to before, and is the first process discussed. The dried granulated slag is ground and is then mixed with a calculated amount of limestone which has been treated similarly. This mixture is a very fine powder and is clinkered in rotary kilns. The clinker is then pulverized very finely and is Portland cement.

Drying and Crushing Plant.

This consists of two Allis & Chalmers rotary driers and a #5 gates gyratory crusher. The driers are long boiler steel cylinders about 40'x5', free to rotate, and driven by gearing. They have a fire-place at one end and a flue at the other. The material to be dried is fed in at the stack end and works its way to the other end where it is discharged into a screw conveyers. The foundations for all these machines are to be built of Portland cement, concrete. They are to be driven by twenty horse power motors. Besides the above acquippment conveyers are to be installed for carrying the raw material from the storage bins, and also conveying and elevating machinery, for transporting the dried materials to the grinding room.

DRYING PLANT DATA.

Machinery	Capacity of Single machine	H. P. requir-ed	Cost (approximate)		
			Machinery	Foundation and Support	Erection or Installation
2 Rotary Dryers	5-10 tons per hr.	20	$3000	$600	$150
1 Gates Crusher #5		50	$1700	$100	$ 50
Totals		70	$4700	$700	$200
Total cost of drying Plant					$5600

Plant For Grinding Raw Material.

From the drying plant the dried materials are carried separately to bins in the grinding plant where the preliminary grinding is done in ball mills. The ball mill in simplest form consists of a revolving cylinder having die plates arranged around the circumference and the grinding is done by steel balls. The perforated die plates are arranged so as to make a series of steps over which the balls drop when the cylinder is rotated, thus grinding the material. The position of the die plates is such that the over size is automatically returned to the action of the balls. The circumference is enclosed by screens through which the ground material passes to a collecting bin. The following table by Allis Chalmers gives this data concerning this type of ball mill.

Size no.	weight without charge of balls	Capacity on Clinkers 20 Mesh.	Power required
7	29500	12-16 Bbbs. per Hr.	30-40 H. P.
8	41100	18-24 " " "	40-50 H. P.

An improved type of ball mill is in the market known as a Kominuter, for which some advantages over the common type of ball mill are claimed. This machine is constructed so as to carry 50% more balls than the #8 ball mill. It requires about the same horsepower as the ball mill and the following claims are made for it;

52 % more screening surface.

50 % " Balls

65 to 85 more output.

The kominuter appears to possess some advantages over the ball mill and therefor, it was decided to use it in connection with this plant.

The fine grinding is done in tube mills, which are steel cylinders measuring 5 X 22 feet. The machine is supported by hollow trunions through which the material is fed and discharged. The cylinder is partly filled with pebbles which do the grinding when the machine is rotated.

DATA FOR GRINDING PLANT.

Machinery	Capacity	H. P.	Cost (Aproximate)		
			Machinery	Foundation	Installation
2 Smidth Kominuter	24 blls	90	$8600		$150
2(5' x 22') Tube mills		100	$5600	$250	$200
Total		190	$9200	$250	$350
Total cost of grinding plant					$9700

Kiln House.

The ground and mixed raw material is brought from the grinding plant to bins at the head of the rotary Kilns. The Kilns are fire-brick lined iron tubes, 100 feet in diameter and 100 feet in length. It was decided to use these long Kilns, since the tendency of modern practice is a long that line. Kilns of 150 feet in length are also coming into use and prove to be economical. The Kilns are supported on rollers and power is applied through a system of gearing. Each Kiln is driven by a 20 H.P. moter and has a capacity of 300 barrels per day. Two 80 foot Kilns would probably do the work but it was thought advisable to allow leeway for shut downs for repairs and other causes.

The cost of one Kiln outfit including Kiln, raw material bin, coal bin and conveyer, will be about $6500.

Kiln Outfit.

2 Kiln (etc)	$13000
3 Coal pulverizers (cyclone)	$ 3600
Briaks for lining and setting Kilns	$ 1200
	$17800

The cooling of the clinker is to be done by piling in heaps in a yard, so no special machinery will be required to accomplish that end.

The clinker grinding plant is in all respects similar to that for grinding the raw material, consisting of two Smidth Kominuter and two #16 tube mills (5' x 22').

Conveying and Elevating Machinery.

For handling crushed limestone.

1 Bucket elevator 36' long.
(suited for vertical position)

For handling granulated slag.

1 Bucket elevator 31' long.
Inclined 60 degrees.
Approximate cost----------$150

For handling dried raw material

1 Pan conveyor----34' long
1 bucket elevator--36 feet long
1 screw conveyor---31 feet long
1 " " --- 16 feet "
cost of above machinery----- $250

For handly ground raw materials.

1 Screw conveyor-----23 feet long
1 Elevator (bucket)--37 " "
1 Screw conveyor-----18 " "
1 Elevator (bucket)--36 " "
(750 inclination)
1 Screw conveyor-----50 " "
Cost-------------------------$500

For handling hot clinker

1 Pan conveyor------55 feet long
1 Elevator(60 degrees) 20 feet long
1 Screw conveyor-------30 " "
Cost---------------------------$250

Cold Clinker handling Machinery.

1 Elevator----------30 feet long
(inclination 60 degrees.)
1 Screw conveyor----40 feet long
Cost---------------------$200

Cement handling machinery.

1 Elevator (bucket)-----------36 feet long
(inclination 75 degrees)------
1 Screw conveyor--------------21 " "
1 " " --------------23 " "
1 Elevator--------------------36 " "
(inclined 60 degrees)
1 Screw conveyor--------------40 " "
1 " " --------------85 " "
Approximate cost-----------------$1000

Cost of Buildings.------------------

As a plant of this kind is to be permanent in character, being located near the blast furnaces and not depending on a natural occuring source of supply; the buildings are to be constructed of brick and steel. The cost of each building will approximate $10000.

Power.

Power is to be supplied to the machinery by induction motors, since they are best suited to the dusty atmosphere of a cement plant. Power will be required as follows;

Drying and crushing Plant-70 H. P.
Grinding " -190 H. P.

Kiln House Plant-------80 H. P.

Clinker Grinding Plant ----------------------190 H. P.

Total--------------------------------530 H. P.

These figures represent the output of the motors.

Cost 600 H. P. Motors tranformers------------$18000

Cost Data.

Drying plant-----------------$	5600
Grinding " -----------------	9700
Kiln House-------------------	17800
Cement grinding---------------	9700
Shafting belts and pulleys and setting up----------	5000
Conveyors--------------------	2350
Buildings and bins------------	30000
Freight----------------------	10000
Plans and specifications and superintendance-----	3000
Office and laboratory---------	1500
Motors-----------------------	18000
Total cost of Plant	$130650

References;

Those already given,

Geological Survey of Ohio,

Manufacture of Hydraulic Cements

(Fourth Series, Bulletin No. 3.)

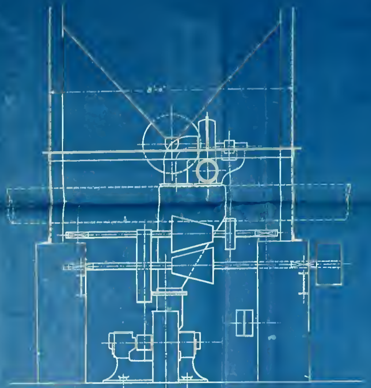


FIG. 1.

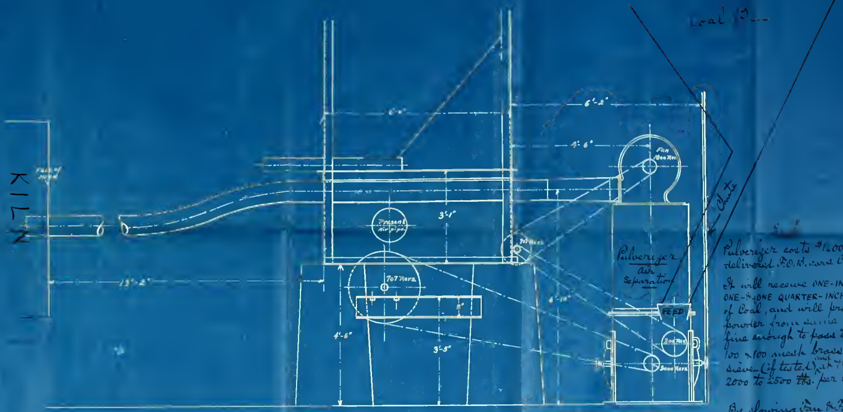


FIG. 3.

The Pulverizer would be placed 10 feet nearer the Kiln than above shown were it not for the Coal Bin being there. It can be driven from the opposite side if desired.

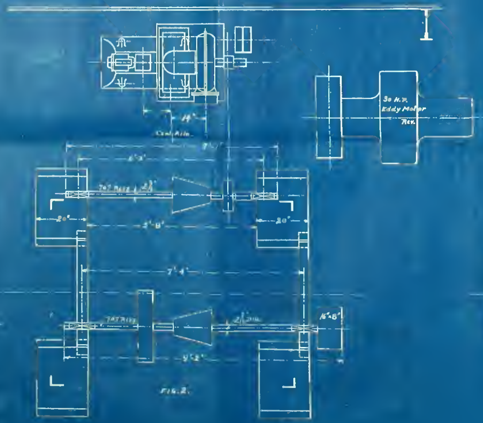


FIG. 2.

General arrangement of
STROUD AIR SEPARATION MILL, "THE CYCLONE PULVERIZER"
and Drives for POWDERED COAL FUEL FIRING of the Rotary Kilns of PORTLAND CEMENT WORKS, without removing the Coal Bins and Air Blast Pipes of the more commonly used System of Firing, so that CHANGE CAN BE INSTANTLY MADE from one System to the other in case of need.

E.H. STROUD & CO.
36 La Salle Street
CHICAGO.

C.P.C. Co. 5-5-03 No. 2526.
Scale 3/8" = 1 foot.

Pulverizer costs $1,200.00 delivered F.O.B. cars Chicago

It will receive ONE-INCH to ONE-&-ONE QUARTER-INCH Screenings of Coal, and will produce a powder from same 95% to 98% fine enough to pass through a 100 x 100 mesh brass wire cloth sieve (if tested) and at the rate of 2000 to 2500 lbs. per HOUR.

By slowing Fan & Feed down to the requirements of the Kiln (say 1000 to 1500 lbs. per hour) a still finer mesh of powder is produ with the advantage that combu tion is improved & there is a sa ing in Coal.

Each Pulverizer requires 15 actual but should be given 20 H.P. so that if should be overfed it can cl itself.

An EXTRA Pulverizer on a car a track (sunken) behind the ro Pulverizers, to relieve any one machines for a few minut case of accidents, is a wi vision. or the old fashione bin &c. shown here can be us

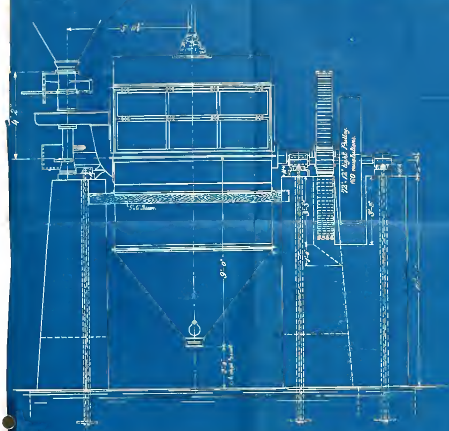
This Pulverizer is far ahea the one you saw in Indian both as to efficiency & dura

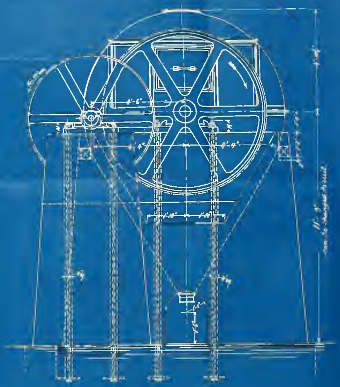
This plan was drawn by Portland Cement Works for t own use

Copy of our Catalogue on f at Armour Institute.

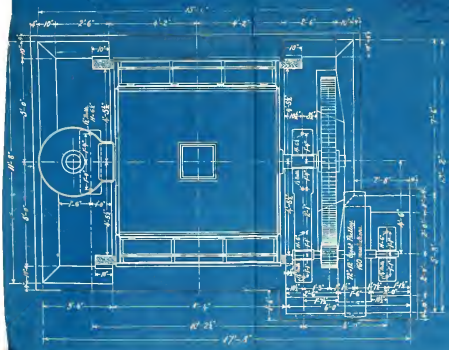
The Lindhard Kominuter No. 66. Patented.

Foundation for Right Hand Mill.





The foundation must be build of portland cement concrete.

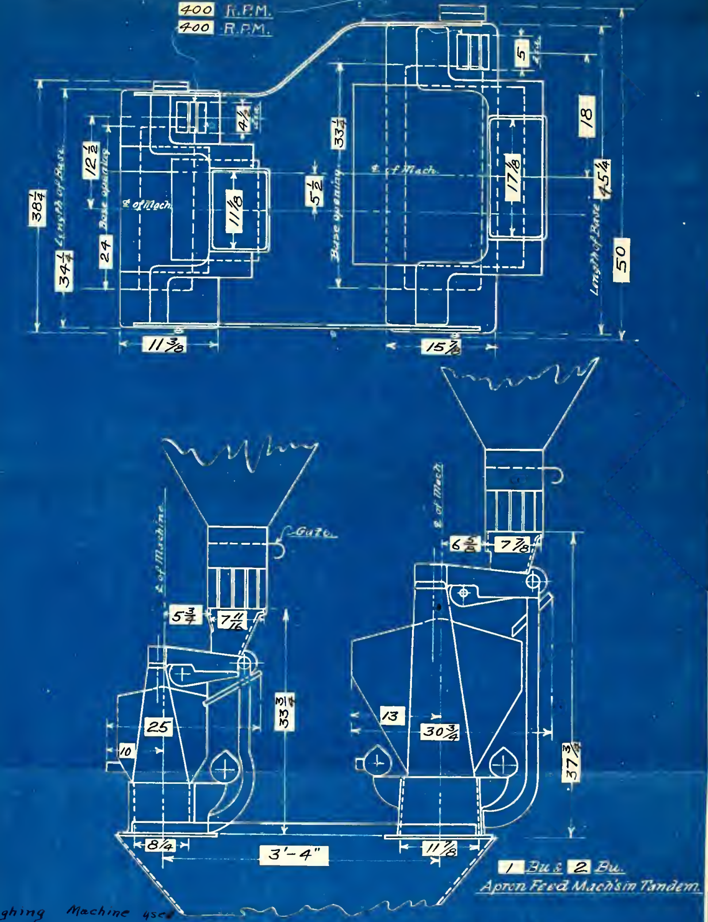


Note. 4" sq. holes around anchor-bolts to be left open until mill is adjusted on foundation.

Scale ½"=1 ft.

7.

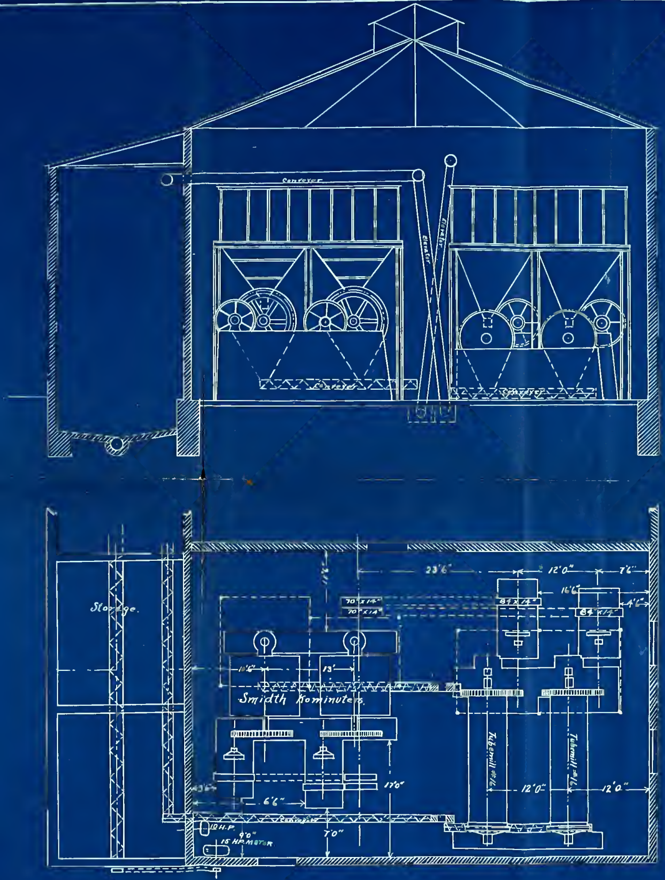
FEB. 14 1902



1 Bu. & 2 Bu.
Apron Feed Mach's in Tandem.

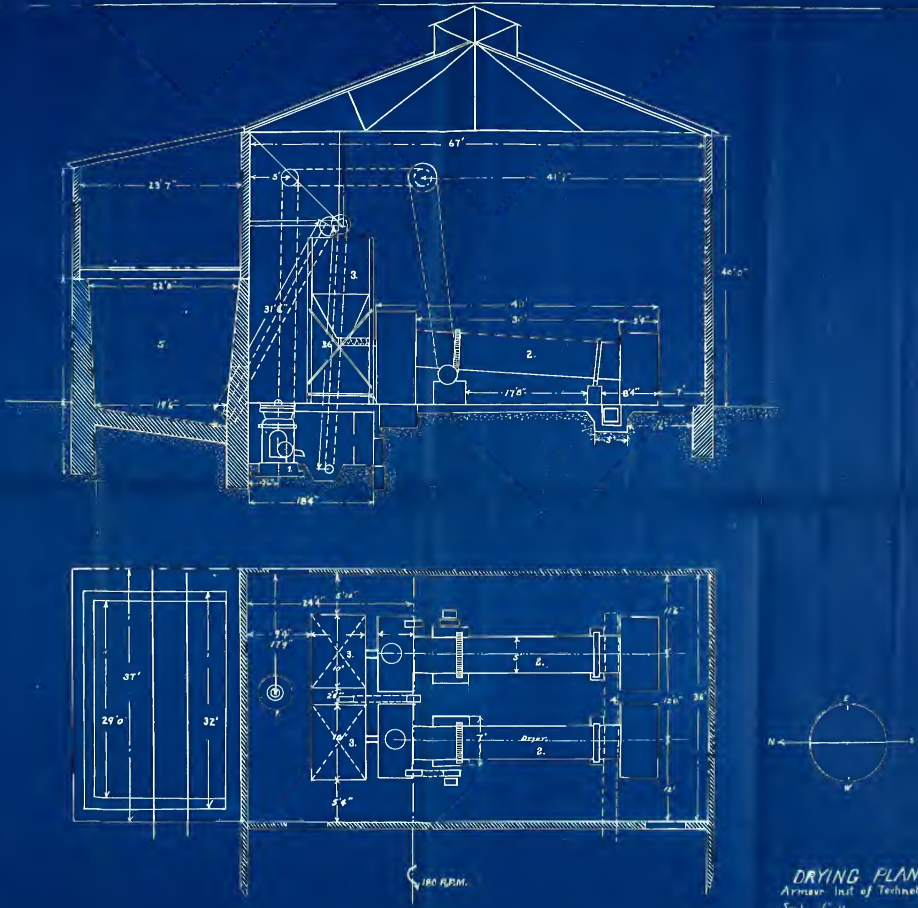
AUTO. WEIGHING MACH. CO.
Jersey City, N.J.

Weighing Machine used
in measuring Raw material)

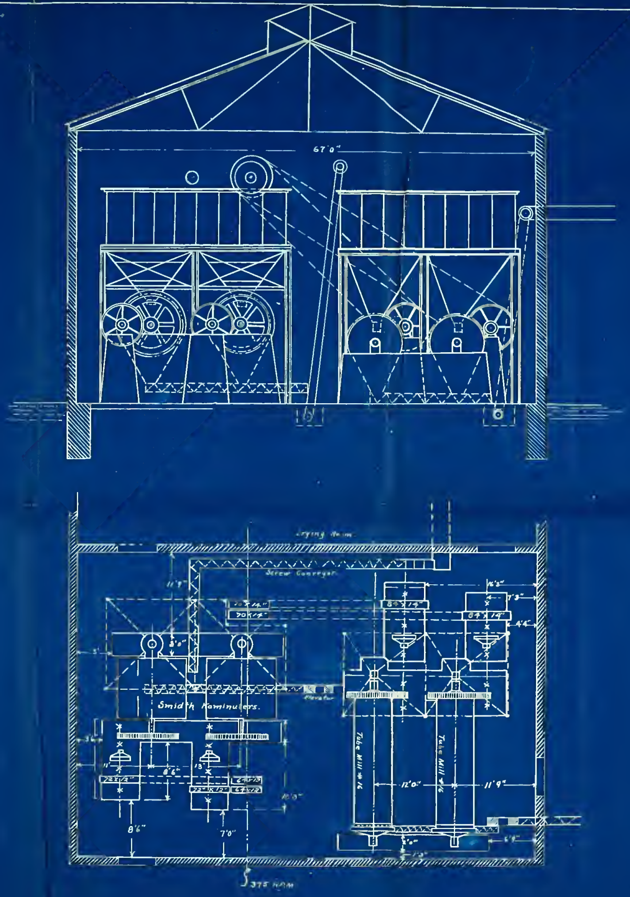


CLINKER GRINDING
PLANT

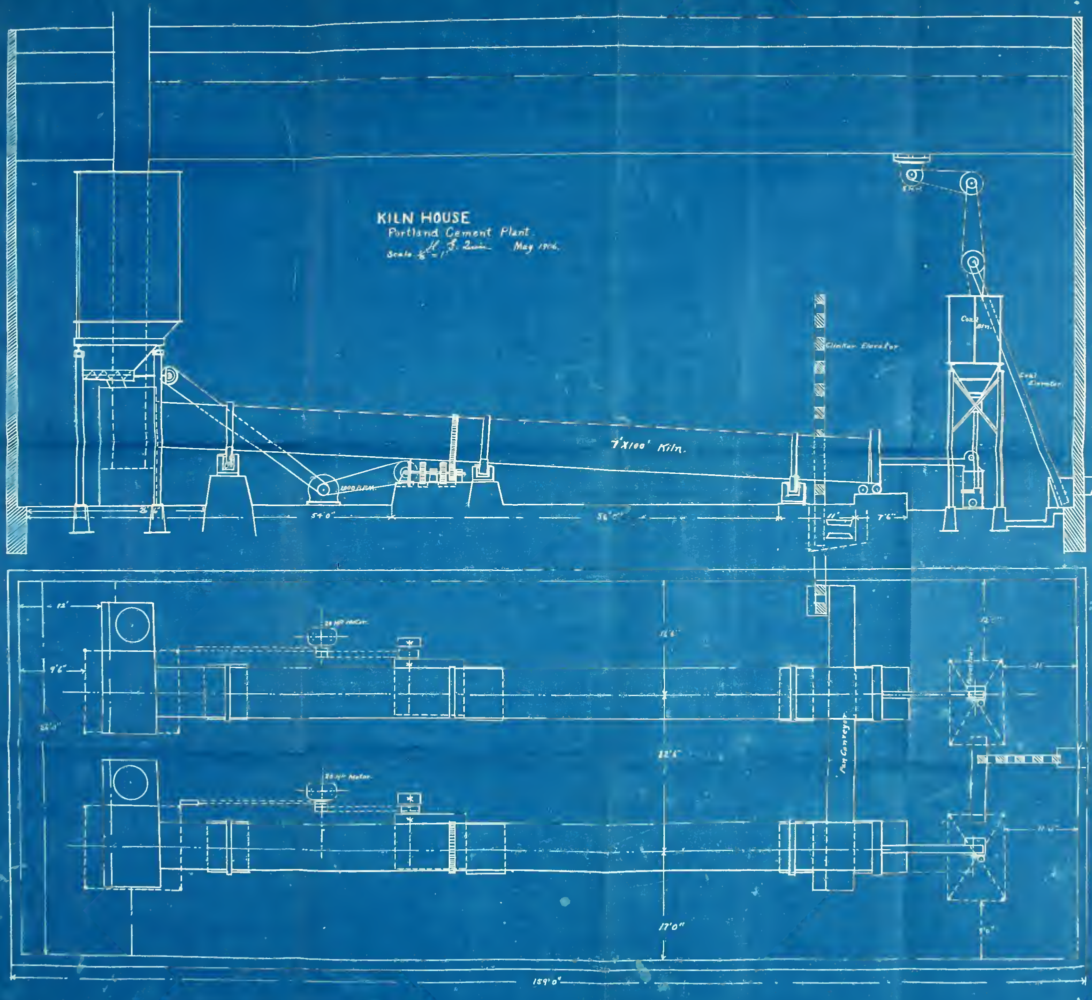
Scale 1/8" = 1'
May. 1906.
H S



DRYING PLANT
Armour Inst. of Technology.
Scale 1/4" = 1'
Mar. 1905.
K. S. Quin.



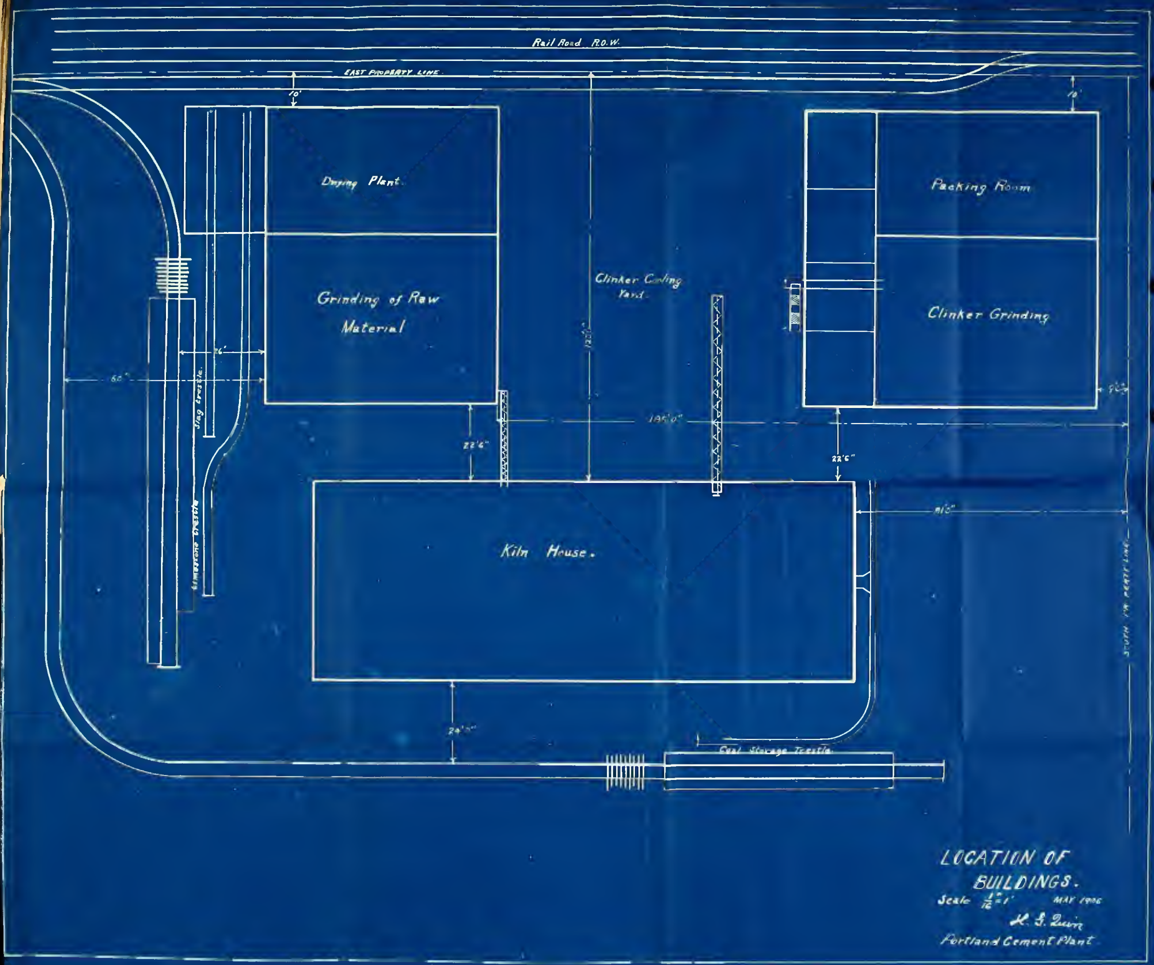
PLANT FOR PREPARING
RAW MATERIAL
Armour Institute of Technology
Scale ¼" = 1'   Mar. 1906.
H. G. Quin.



KILN HOUSE

Portland Cement Plant.

Scale 1/8"=1'   H. F. Lewis   May 1906.



LOCATION OF BUILDINGS.

Scale $\frac{1}{16}$" = 1' MAY 1906

H. S. Quin

Portland Cement Plant